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Climate-financial trap: an empirical approach to detecting situations of double vulnerability

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Executive Summary

The present study proposes to build a systematic approach to detecting and specifying situations of double vulnerability. Double vulnerability refers to a situation where a country combines climate and macro-financial vulnerabilities. It is defined as a situation where climate change (either in the form of occasional shocks or chronic deterioration in climate conditions) is likely to have multidimensional impacts on populations, ecosystems and economic activity, leading to an increase in fiscal imbalances and public debt ratios in the short to medium term. In turn, this negative dynamic limits governments' ability to deal effectively with the consequences of climate change in the future, and in particular to support the most vulnerable segments of the population. We refer to this vicious circle as a "climate-financial trap".

For each of these two dimensions, we construct vulnerability indexes for all countries. By combining these two dimensions, this study identifies different groups of countries facing a double vulnerability situation to varying degrees. As far as vulnerability to extreme weather events is concerned, many islands in the Pacific, Indian Ocean and Caribbean regions appear to be in a situation of double vulnerability. In addition, some Latin American coastal countries, two African countries and two Southeast Asian countries are also highly vulnerable. In terms of vulnerability to chronic deterioration in climate conditions, countries in the Mediterranean, Gulf of Aden and Middle East regions, as well as most of West African coastal countries, also fall into the group of highly vulnerable countries.

Based on this analysis, this study assesses some empirical strategies and financial instruments which are likely to mitigate the primary consequences of climate change on the dynamics of public finances for the identified groups of countries. These strategies combine efforts to reduce (or to share) the rising and unpredictable costs of climate shocks in the short run and to maintain the fiscal space needed to support ambitious adaptation investment strategies, in order to mitigate the costs of future climate shocks in the long run. Whether such strategies can break the dynamics of the "climate-financial trap" remains an open question for further work.

The author wishes to thank Maxime Terrieux for his contribution to the present study.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) published in March 2023 points out that current mitigation efforts are insufficient to limit global warming to 1.5°Celsius above pre-industrial levels. The 2°Celsius ceiling agreed upon in 2015 as part of the Paris Agreement could also be exceeded. The consequences of this increase in temperature on ecosystems and human life are not yet fully known. This temperature increase could lead to geoclimatic tipping points being exceeded, inducing a dynamic of rapid, non-linear worsening in climate conditions.

The *Climate Policy Initiative* think tank estimates the amount of climate finance investments[1] at approximately USD 850-940 billion in 2021 (CPI, 2022). According to this institution, the amount of investment needed to stay on track for a temperature increase limited to 1.5°C and avoid the main consequences of climate change is around 4,300 billion USD by 2030. Various studies also confirm that the overall cost of the low-carbon transition, although particularly high in the coming years, would increase if these investments were delayed.

Moreover, in an uncertain international financial context, the most indebted countries are experiencing severe pressure on public finance balances, in particular on public debt repayment. The combination of vulnerability to climate change and increased pressure on public finances is likely to lead to trajectories of rapid public debt unsustainability (IMF, 2022c).

1 These are national and domestic flows to finance climate investments.

1. Background and Definitions

The issue of double vulnerability is raised in a political context conducive to the evolution of the international financial architecture for climate. Indeed, climate vulnerability has fueled many discussions at COP 26 in Glasgow, at the World Bank and International Monetary Fund (IMF) Annual Meetings in October 2022 and at COP 27 in Sharm-El-Sheik.

To cite only two examples, the launch of the Bridgetown Initiative at COP 26 and the agreement reached to establish a *Loss and Damage* Fund at COP 27 have confirmed the need to consider climate change vulnerability and macro-financial vulnerability together. In particular, the Bridgetown Initiative calls for an acceleration of the public debt restructuring process for vulnerable countries[2]. The Initiative also calls for funding the massive adaptation investment needs through different types of resources, including a new Special Drawing Rights (SDR) issuance. In June 2023, the Paris Summit for a New Financial Pact also called for a better definition of climate and financial vulnerabilities. This renewed conceptual framework could lead to revise the criteria for allocating Official Development Assistance.

In this study, a situation of climate vulnerability is defined as a situation where a country (i) **is highly exposed** to extreme weather events or chronic deterioration in climate conditions (ii) as well as being **relatively more sensitive than other countries** to the materialization of these shocks. The exposure is understood as the probability of occurrence of climate shocks or chronic deterioration in climate conditions, while sensitivity is understood as the potential physical damage caused in the event of such phenomenon (whether occasional or chronic). In this respect, this study adopts a definition widely used in the literature on vulnerability to exogenous shock, whatever their nature. These definitions are also consistent with the IPCC definition of climate vulnerability (IPCC, 2022). [3]

Macro-financial vulnerability is defined as the government's ability (or inability) to mobilize, when necessary, sufficient domestic or international financial resources to avoid an excessive deterioration in annual budget execution or pressures on public debt repayment.

2 For a description of the DSSI mechanism: https://www.worldbank.org/en/topic/debt/brief/covid-19-debt-service-suspension-initiative.
For a description of the Common Framework and country eligibility criteria, see for example: https://clubdeparis.org/sites/default/files/annex_common_framework_for_debt_treatments_beyond_the_dssi.pdf.

3 The IPCC defines vulnerability in a relatively generic way and admits that the notion can have a broad meaning depending on the context: "The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." (IPCC 2022)

2. An empirical approach to detecting situations of double vulnerability

According to Section 1, countries in a situation of double vulnerability face intense climate shocks or are particularly vulnerable to chronically deteriorating climate conditions. In addition, the cost of these climate events regularly jeopardizes fiscal balance and generates pressure on public debt repayment, especially on foreign currency-denominated debt. In turn, these negative dynamics limit governments' ability to cope effectively with the consequences of climate change in the future, and in particular to support the most vulnerable. We assume that such a vicious circle may be a proxy for detecting a "climate-financial trap" phenomenon[4].

To identify those countries in a situation of double vulnerability, this study constructs a set of indicators for each vulnerability which, once combined, are likely to give a good sense of the extent of double vulnerability in each country[5].

To estimate climate vulnerability, this study uses an AFD proprietary database with the following characteristics:

- For each country, climate vulnerability is assessed separately according to whether the climate hazard corresponds to an occasional climate shock (e.g., cyclone, flood) or a chronic deterioration in climate conditions (e.g., sea level rise);
- The Climate Vulnerability Index (see Appendix 1) reflects both the country's exposure to these climate shocks and its sensitivity (risk of water scarcity, number of inhabitants exposed to rising sea levels, etc.);
- When possible, the indices are based on scenarios of future climate conditions (IPCC scenarios in particular);
- Indices are available for over 160 countries. For countries not covered, it is proposed to extrapolate the available data from the nearest country with similar climate characteristics;

To assess macro-financial vulnerability, we use sovereign risk ratings produced by credit rating agencies. Despite their limitations[6], these ratings offer the following features, which are useful for our study:

- Sovereign ratings reflect an estimate of the probability of default on public debt, with an emphasis on foreign currency-denominated debt;
- They cover a wide geographical scope, thus avoiding incomparability across countries;

Where available, we use the ratings produced by the three main rating agencies (Moody's, Standard & Poor's, Fitch) from which we select the lowest of the best two ratings[7]. For unrated countries, a CCC rating is applied when the country is at high risk of, or in debt distress, as defined by the IMF[8]. For the few remaining countries, we use our knowledge of the country's economic situation.

On this basis, we identify the most vulnerable countries using a simple graphical representation that crosses the Climate Vulnerability Index with the macro-financial vulnerability level as defined above. Given that we have distinguished between two types of climate vulnerability (vulnerability to occasional shocks or chronic deterioration in climate conditions), we identify situations of double vulnerability in two graphs (see below). The intersection of vulnerability to extreme weather events and macro-financial vulnerability reveals three groups of countries.

4 Further work would be necessary to formally specify such a phenomenon and describe it theoretically. This is beyond the scope of this study.

5 It should be noted that this study does not establish a causal link between the two dimensions. Further work would be needed to formally establish such a link.

6 One of these limitations is the limited time horizon for estimating the probability of default (often less than 5 years).

7 In the following sections, we consider countries with a rating of 15 or above (equivalent to B for Standard & Poor's and Fitch, and B2 for Moody's) to be in a situation of particular macro-financial vulnerability.

8 The public debt sustainability analysis is assessed by the IMF and the World Bank according to a defined framework, with a distinction between low-income countries (LIC-DSA, more details here) and higher-income countries with the ability to borrow on international markets (MAC-DSA, more details here).

Figure 1 a: Countries in a double vulnerability situation: vulnerability to extreme weather events, and micro-financial vulnerability

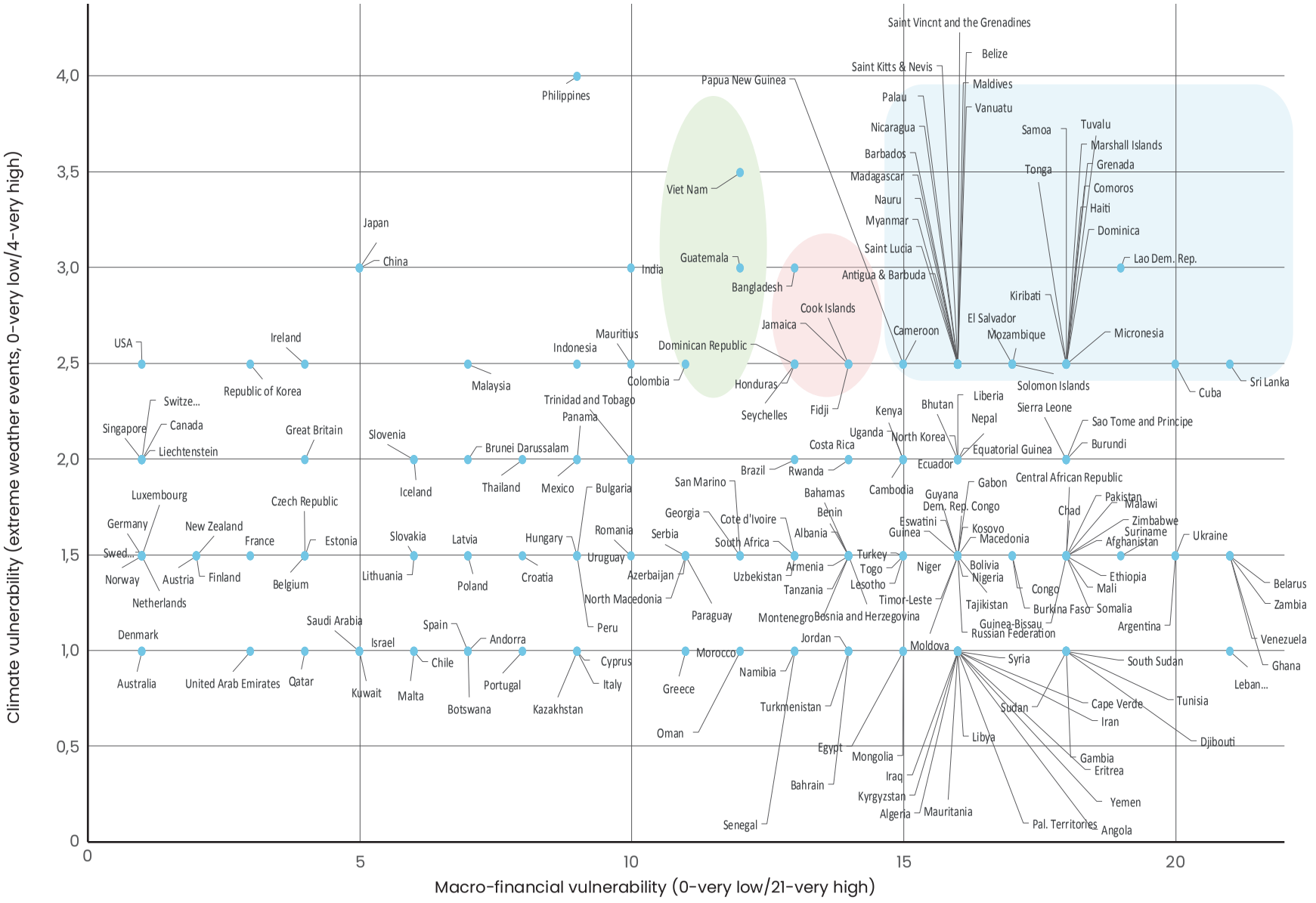

Table 1.a: Country groups by vulnerability to extreme weather events and macro-financial vulnerability

	VULNERABILITY TO EXTREME WEATHER EVENTS	
	CATEGORY	**COUNTRY**
MACRO VULNERABILITY	**O++**	**Caribbean:** Antigua and Barbuda, Barbados, Cuba, Dominica, Grenada, Haiti, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines. **Pacific Ocean:** Nauru, Palau, Papua-New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Kiribati, Micronesia, Marshall Islands **Indian Ocean:** Comoros, Madagascar, Maldives, Sri Lanka **Latin American coastal countries:** Belize, El Salvador, Nicaragua **Africa:** Cameroon, Mozambique **Southeast Asia:** Laos, Myanmar
	O+	Jamaica, Cook Islands, Fiji, Honduras, Bangladesh, Dominican Republic, Seychelles
	O	Colombia, Vietnam, Guatemala

The first group (blue rectangle, O++) includes countries with elevated macro-financial vulnerability, characterized by a particularly high level of public debt. Due to their geographical location, these countries are also among the most exposed and vulnerable to extreme weather events. This category includes many islands in the Caribbean, Pacific and Indian Oceans. Because of their size, these countries often have limited room for fiscal adjustments and limited investment capacity. There are also a number of Central American coastal countries that are both vulnerable to the increasing importance of climate phenomena, but also suffer from a fragile macro-financial situation related to structural factors (structurally high public debt, position in international trade, insufficient diversification of the productive base, etc.). Two African countries are also included in this category (Cameroon and Mozambique) because they are vulnerable to extreme rainfall events (Cameroon) or cyclone penetration (Mozambique) and also present multifactorial macro-financial vulnerability.

These countries are likely to incur high and unsustainable costs for reconstruction and economic recovery support after extreme weather events. One of the challenges is to prevent these additional expenses from crowding out priority expenses for long-term development on the one hand, and leading to unsustainable debt dynamics on the other hand. Mitigating the negative impact of these unpredictable additional costs is critical in order to avoid further increasing macro-financial vulnerability (see Section 3).

The second group (pink oval, O+) comprises countries whose macro-financial vulnerability is relatively lower, but which are highly vulnerable to specific climate phenomena. These countries also present at least one factor of macro-financial fragility (e.g. fiscal or balance of payments imbalance) which a high-intensity climate shock or a repetition of shocks at short intervals could significantly reinforce.

The last group of countries (green oval, O) is interesting in view of the role they play in global growth dynamics. These countries have stronger macro-financial fundamentals but they are highly vulnerable to extreme weather events. Colombia and Vietnam fall into this category. As these economies play a leading role in regional growth dynamics, a permanent economic slowdown in these countries could have long term consequences for the region. At the same time, the intersection of vulnerability to chronic deterioration in climate conditions and macro-financial vulnerability reveals the following three groups of countries.

Figure 1 b: Countries in a double vulnerability to chronic deterioration in climate conditions, and macro-financial vulnerability

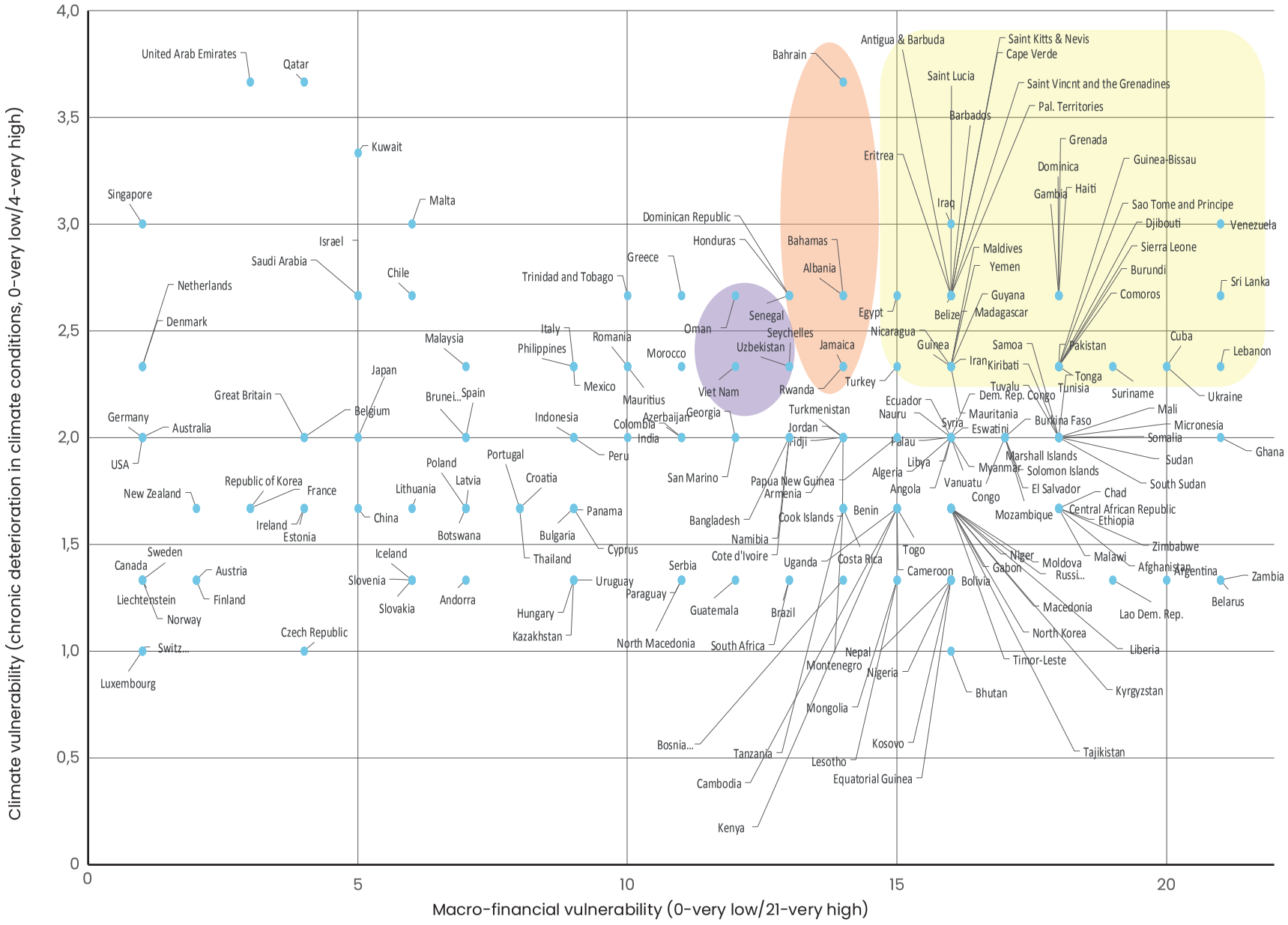

Table 1.b: Country groups by vulnerability to chronic deterioration in climate conditions and macro-financial vulnerability

	VULNERABILITY TO CHRONIC DETERIORATION IN CLIMATE CONDITIONS	
	CATEGORY	**COUNTRY**
MACRO VULNERABILITY	**C++**	**Caribbean:** Antigua and Barbuda, Barbados, Dominica, Grenada, Haiti, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Cuba. **Indian Ocean:** Comoros, Madagascar, Maldives, Sri Lanka. **Latin American coastal countries:** Belize, Venezuela, Nicaragua, Guyana, Suriname. **Mediterranean region:** Egypt, Lebanon, Palestine, Tunisia, Turkey **Gulf of Aden and Middle East:** Yemen, Djibouti, Eritrea, Iran, Iraq **West African coastal countries:** Cape Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Sierra Leone+ São Tomé and Príncipe **East Africa:** Burundi **South Asia:** Pakistan **Central Europe:** Ukraine
	C+	Bahrain, Bahamas, Albania, Dominican Republic, Honduras, Senegal, Jamaica, Rwanda
	C	Oman, Seychelles, Uzbekistan, Vietnam

The first group of countries (yellow rectangle, C++) includes those most vulnerable to chronic deterioration in climate conditions (sea level rise, hydric stress and thermal stress), and countries which also present a high level of macro-financial vulnerability. These include some island countries in the Caribbean and the Indian Ocean which are vulnerable not only to rising sea levels, but also to a sharp increase in temperatures. This category also includes certain coastal Latin American countries, where economic activity and housing are sometimes concentrated in coastal areas. These countries are exposed to rising sea levels and rising temperatures, generating particularly negative interactions between climate conditions and human activity. This category also includes countries in the Mediterranean region that are particularly exposed to rising temperatures and scarcity of water resources. The combination of these two factors may have significant consequences on the agricultural sector (for example in Egypt, Tunisia). It also includes countries in the West African coastal zone exposed to rising sea level. As economic activity and housing are largely concentrated in the coastal zone, the consequences of rising sea level will be particularly critical in this region. Finally, this category includes countries in the Gulf of Aden and the Middle East, where rising temperatures could exceed the critical threshold for habitability. In some countries of this category, chronic deterioration in climate conditions may also regularly result in acute episodes listed as occasional shocks (floods, drought, etc.) that threaten the viability of certain regions (Pakistan, Burundi, etc.).

For countries in this category, one of the challenges of reducing climate vulnerability will be to organize the spatial reconfiguration of housing and economic activity. It will also involve investing in less water-intensive production processes or adapting production systems to changing climate conditions. However, the macro-financial vulnerability of most of these countries constrains investment capacity.

The second group of countries (orange oval, C+) includes countries with at least one factor of macro-financial vulnerability. In addition, these countries are structurally vulnerable to deteriorating climate conditions due to their geographical location (Bahamas, Dominican Republic, Jamaica, Honduras, Senegal) or their limited access to water resources (Bahrain). For these countries, an acceleration of chronic deterioration in climate conditions could lead to unsustainable debt dynamics and fiscal imbalances in the mid-term.

The last group (purple oval, C) includes countries whose macro-financial fundamentals are stronger but which remain highly vulnerable to deteriorating climate conditions. It is important to pay attention to the adaptation trajectory of Uzbekistan and Vietnam for example, as these economies play an important role in regional economic dynamics. Moreover, these countries

have made ambitious commitments to mitigate greenhouse gas emissions. The fiscal space and investment capacity available will need to be allocated to adaptation and mitigation investments so that these countries can meet their own targets.

The table below summarizes the groups identified above, adding the following criteria for a complete overview:[9]

- LDC and SIDS countries are marked in green.
- Middle Income Countries (MIC) that do not belong to the Small Island Developing States (SIDS) group are noted in blue.
- Countries at high risk of, or in public debt distress according to the IMF are underlined.

Table 1.c: Summary table of results

	CLIMATE VULNERABILITY (EXTREME WEATHER EVENTS)		CLIMATE VULNERABILITY (CHRONIC DETERIATION IN CLIMATE CONDITIONS)	
	CATEGORY	COUNTRIES	CATEGORY	COUNTRIES
MACRO-FINANCIAL VULNERABILITY	O++	**Caribbean:** Antigua and Barbuda, Barbados, Cuba, Dominica, Grenada, Haiti, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines **Pacific Ocean:** Nauru, Palau, Papua-New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Kiribati, Micronesia, Marshall Islands **Indian Ocean:** Comoros, Madagascar, Maldives, Sri Lanka **Latin American coastal countries:** Belize, El Salvador, Nicaragua **Africa :** Cameroon, Mozambique **Southeast Asia:** Laos, Myanmar	C++	**Caribbean:** Antigua and Barbuda, Barbados, Dominica, Grenada, Haiti, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Cuba **Indian Ocean:** Comoros, Madagascar, Maldives, Sri Lanka **Latin American coastal countries:** Belize, Venezuela, Nicaragua, Guyana, Suriname **Mediterranean region:** Egypt, Lebanon, Palestine, Tunisia, Turkey **Gulf of Aden and Middle East:** Yemen, Djibouti, Eritrea, Iran, Iraq **West African coastal countries:** Cape Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Sierra Leone + São Tomé and Príncipe **East Africa:** Burundi **South Asia:** Pakistan **Central Europe :** Ukraine
	O+	Jamaica, Cook Islands, Fiji, Honduras, Bangladesh, Dominican Republic, Seychelles	C+	Albania, Bahamas, Bahrain, Dominican Republic, Honduras, Senegal, Jamaica, Rwanda
	O	Colombia, Vietnam, Guatemala	C	Seychelles, Uzbekistan, Vietnam, Oman

It is worth mentioning that some countries with high macro-financial vulnerability are also vulnerable to both occasional, extreme weather events, and chronic deterioration in climate conditions. A number of islands in the Caribbean and Indian Ocean (Antigua and Barbuda, Barbados, Dominica, Cuba, Grenada, Haiti, Saint Kitts & Nevis, Sainte Lucia, Saint Vincent & Grenadines, Comoros, Madagascar, Maldives and Sri Lanka), as well as some Latin American costal countries (Belize, Nicaragua) fall into this group. These countries may be under particular pressure to cope with multifactorial climate threats, while having limited investment capacity to mitigate these impacts (see Section 3).

9 This classification is as of August 2023.

3.
Which financial strategies to cope with a situation of double vulnerability?

The countries identified in Section 2 are likely to be in a situation of double vulnerability. They are particularly vulnerable to frequent and intense climate shocks, or to chronic deteriorating climate conditions. Some are vulnerable to both of them. Changing climate conditions can have major consequences on populations, ecosystems and economic activity. Coping with these situations requires substantial public spending to absorb the direct social costs of climate shocks and support economic recovery. In macro-financial vulnerable countries, such increasing post-shocks public expenses can worsen fiscal imbalances and accelerate public debt accumulation. In turn, this negative dynamic on public finances can significantly reduce governments' long-term investment capacity. Yet, adaptation investments are critical to mitigate the impacts of future climate shocks. We refer to this vicious circle as a "climate-financial trap". It defines a situation where vulnerable countries are unable to invest to reduce the costs of future climate shocks due to the rapidly rising costs of current shocks.

We hypothesize that two complementary financial strategies can effectively break this vicious circle: (i) to reduce (or to share) the rising and unpredictable costs of climate shocks in the short run and (ii) to maintain the fiscal space needed to support ambitious adaptation investment strategies, in order to mitigate the costs of future climate shocks in the long run.

This section adapts these two complementary financial strategies to the characteristics of the six groups of countries identified in the previous section. Indeed, the levels of climate and macro-financial vulnerabilities largely determine countries' priorities and ability to cope with climate change consequences.

For countries most vulnerable to extreme weather events and with high macro-financial vulnerability (O++ group), two priorities stand out:

(i) avoid a situation of marked tension on public finances, or even unsustainable public debt accumulation, after each climate shock (mitigate the "liquidity risk");
(ii) maintain the fiscal space needed to set-up macroeconomic instruments designed to at least mitigate the effects of climate shocks in the medium and the long run (mitigate the "solvency risk");

Instruments that can help achieve these priorities are risk retention support instruments[10] coupled with risk transfer mechanisms. Indeed, this group of countries includes those whose public finances are unable to bear the cost of frequent climate shocks. Strengthening risk retention capacity through Climate Resilient Debt Clauses (CRDC) or contingent loans may prove insufficient, or even undesirable for countries whose public debt repayment capacity in the medium-term is particularly fragile. International public insurance instruments, if accompanied by a subsidized redistributive mechanism, can help absorb the costs of climate shocks while avoiding unsustainable dynamics in public finances.[11]

For countries highly vulnerable to extreme weather events but with moderate macro-financial vulnerability (O+), the strategy would aim to:

(i) strengthen risk absorption capacity by reducing the related cost to public finances;
(ii) maintain access to international markets despite the occurrence of a shock;
(iii) facilitate reconstruction and accelerate economic recovery.

For this group of countries, the cost of extreme weather events for households and companies can be partially mitigated through large-scale public or private insurance mechanisms[12]. Of course, such insurance mechanisms must be developed under acceptable financial and legal conditions (the issue of regulating this market is key here)[13]. In addition, pre-arranged financing, including contingent loans, can also provide additional resources to strengthen the government's risk

10 Risk retention refers to a situation where governments, financial institutions, companies or other economic agents retain risk on their own balance sheet, and directly bear the consequences should this risk materializes. This concept is defined in contrast to risk transfer, which refers to a situation where an economic agent offers to bear the risk (at least its financial consequences) to another agent. Contingent loans or Climate Resilient Debt Clauses are considered risk retention instruments, as they support governments to better manage climate-related risks on their own. There is no formal transfer of responsibilities for risk compensation in this case. Conversely, risk-sharing mechanisms (including insurance instruments) are considered risk transfer mechanisms, as they relieve governments from the responsibility of absorbing costs related to the materialization of climate-related risks.

11 A detailed review of the financial instruments mentioned in this section is provided in Appendix 2.

12 Although not the focus of this study, see for example Jain, Chida, Pathak *et al.,* 2022 for a critical review on the challenges of developing insurance instruments in the context of Pacific SIDS.

13 Where appropriate, cat bonds may also help to provide affordable prices for insurance instruments. These instruments are based on an underlying model of risk transfer to institutional investors, who can pool risks at a regional or international level.

retention capacity in the event of a shock, while maintaining access to international liquidity. In concrete terms, the introduction of macroeconomic instruments designed to automatically compensate households and companies (natural disaster compensation system) and to support rapid economic recovery (Liquidity facilities for companies, automatic loan restructuring process, deferral of tax payments, etc.) are important components of such a strategy.

For countries with high vulnerability to extreme weather events but some macro-financial strength (Category O), the strategy could focus on:

(i) setting up macroeconomic instruments for rapid shock absorption;
(ii) expanding the range of risks covered through market insurance mechanisms;
(iii) including the most vulnerable populations in mechanisms that support economic recovery.

Risk transfer mechanisms, including insurance instruments, often exist in this group of countries. The challenge could be to extend sectoral coverage to sectors deemed more vulnerable to extreme weather events (agriculture and housing for example) and to vulnerable groups such as young workers, women, and people living in remote areas, etc. The overall objective of this strategy would be to avoid increasing socio-economic inequalities due to unequitable compensation and limited support during the recovery. Macro-financial strength is also an opportunity to invest substantially in adaptation in order to reduce the costs of extreme climate events in the medium and the long run, especially for most vulnerable populations.

For countries vulnerable to chronic deterioration in climate conditions and with elevated macro-financial vulnerability (category C++), the strategy would focus first and foremost on rebuilding fiscal space in the short term to support transition. Unlike countries that are primarily vulnerable to extreme weather events, focusing on climate risk coverage may not necessarily be relevant as the consequences of chronic deterioration in climate conditions are much more systemic. The impacts on populations, ecosystem and economic activity will be multifactorial, requiring structural changes rather than a risk-hedging approach. The overall cost of these impacts would gradually become unsustainable for households, businesses and, ultimately, public finances. In this context, priorities could include:

(i) Reducing debt service expenses to avoid an insolvency dynamic in the short term;
(ii) Developing adaptation strategies in the most vulnerable sectors, and reallocating financial resources to mitigate multifactorial climate vulnerability.

For countries in this category with particularly high levels of debt, a concerted debt restructuring process may be the only way to return to sustainable public debt dynamics in the current international financial context. Some countries with fewer critical macro-financial vulnerabilities, but with very limited additional indebtedness capacity, have also undertaken debt-for-climate swaps (see Appendix 2). Countries with lower macro-financial vulnerability have also resorted to *sustainability-linked bonds* (SLB), some of which are associated with financial incentives in exchange for achieving predefined "green" targets.

For countries with major vulnerability to chronic deterioration in climate conditions but with no critical macro-financial vulnerability (category C+), the strategy would aim to:

(i) avoid deterioration in international refinancing conditions and associated negative signals;
(ii) invest massively in a climate change adaptation trajectory;
(iii) set up macroeconomic crisis management instruments in the event of critical episodes (heat wave, rising sea levels, etc.).

Various domestic and international financial instruments may help finance long-term public investment in adaptation. However, for countries in this group, mainly middle-income countries, one of the challenges may be to access concessional international financial resources. Indeed, due to the low average rate of return on adaptation investments, tapping international concessional funding sources may be critical to complement domestic resources in order to finance adaptation strategies on viable financial terms. Instruments such as SLBs or direct donor financing (including from the recent IMF Resilience and Sustainability Trust) can have the advantage of offering viable financial conditions for adaptation investments. In a number of countries in the C+ group, development of private insurance mechanisms, whether or not supported by public authorities, could also help support strategic sectors such as agriculture or tourism.

For countries with high vulnerability to chronic deterioration in climate conditions but with some macro-financial strength (Category C), the strategy would aim to:

(i) extend support mechanisms for rapid economic recovery to the most vulnerable segments of the population;
(ii) invest massively in climate change adaptation;
(iii) reduce the risk of trade-off between support to adaptation and mitigation efforts.

Disaster compensation systems and support mechanisms for rapid economic recovery usually exist in these countries. As previously mentioned, strengthening their inclusiveness helps to avoid the risk of exacerbating inequalities related to the effects of climate change. A number of countries in this group are also very active on the international debt market. It may be worth mentioning here that Green Bonds can be structured to focus simultaneously on mitigation and adaptation strategies. Indeed, one of the challenges for countries in this group is to invest in climate change adaptation while financing mitigation efforts required to achieve their own greenhouse gas reduction targets. The development of carbon markets can also reduce this risk of trade-off, as they generate additional tax revenues which can be reallocated to either mitigation or adaptation investments, or both.

Conclusion

Improvements in the quality and availability of climate data since IPCC's early work have led to a better understanding of the complexity of climate change's impacts on natural, economic and social systems.

This study proposes to define a situation of double vulnerability, where a country is vulnerable to the consequences of climate change on the one hand, and to the deterioration of its macro-financial profile on the other. When climate change-related costs worsen fiscal imbalances and affect public debt repayment capacity, governments may lack investment capacity to mitigate the cost of future climate shocks. We refer to such vicious circle as a "climate-financial trap".

We identify different groups of countries likely to be vulnerable to this negative interaction between climate and macro-financial vulnerability. Further work could usefully be carried out to theoretically characterize these negative interactions and simulate them in existing contexts.

Based on identified situations of double vulnerability, this study assesses various financial strategies to help reduce the rising costs of climate shocks in the short run and maintain the fiscal space needed to support ambitious adaptation investment strategies in the long run.

Appendix 1 – A methodology for measuring climate vulnerability

The Climate Vulnerability Index we use provides ratings for five sub-criteria that distinguish between vulnerability to extreme weather events and vulnerability to chronic deterioration in climate conditions. The five sub-criteria are water stress level, heat stress level, exposure to extreme precipitation, exposure to sea level rise and exposure to cyclones. They are further detailed below:

Table 2: Climate vulnerability sub-criteria

WATER STRESS	The water stress indicator measures the change in frequency and intensity of water shortages.	The water stress indicator is built from climate projections, data on current water shortages and projections on the evolution of water demand in a given territory. This indicator measures the risk of increased frequency and intensity of water shortages. The indicator includes variables of absolute and relative change in water resource and demand between today and 2040. Water shortages are caused by human activities (increased demand) and/or climate trends (reduced natural water supply). Source : World Resources Institute
HEAT STRESS	The heat stress indicator measures the change in frequency and intensity of heat waves.	The heat stress indicator measures the relative change in the frequency and severity of hot days, as well as the change in annual maximum temperatures, between climate projections (2030-2040) and historical data (1975-2005). It does not capture the hottest territories but territories that will experience a significant and unusual rise in temperatures. Indeed, it is in these territories that heat will have the strongest impacts on the health of residents, on the performance of infrastructure networks and on energy demand and cost. Source : Coupled Model Intercomparison Project (CMIP) 5, IPPC
EXTREME PRECIPITATION	Extreme precipitation measures the change in frequency and intensity of heavy rainfall events.	The extreme precipitation indicator measures the increase in frequency and intensity of extreme precipitation events and incorporates a sub-indicator of historical data on the number of floods recorded between 1985 and 2011. Extreme precipitation can have dramatic consequences in terms of public health and mortality and can damage buildings and infrastructure. Source : CMIP5, IPPC
SEA LEVEL RISE	The sea level rise indicator measures the proportion of coastal land that will be affected by the end of the century.	The sea level rise score reflects the proportion of coastal land that will be affected by the effects of rising sea levels and coastal storms at the end of the century. Source: Notre Dame Global Adaptation Initiative (ND-GAIN)
CYCLONES	The cyclone indicator measures historical exposure to cyclones, hurricanes and typhoons.	The cyclone indicator measures historical exposure to cyclones, hurricanes and storms between 1980 and 2016. The indicator studies both the severity and frequency of cyclones using wind speed data. Cyclones are measured on the basis of historical data, due to the inability of current climate models to project individual events. Given that cyclones will most likely occur in the same geographical areas with a higher intensity, and perhaps a higher frequency, this method allows for a good risk assessment given the current state of science. Source : International Best Track Archive for Climate Stewardship (IBTrACS) version 3

Each sub-criterion is scored on an absolute scale from 0 to 100 before being projected on a scale of 1 to 4 based on the country's score relative to the sample. The breakdown is as shown in the following table.

Table 3: Estimating the relative Climate Vulnerability Index

LEVEL OF VULNERABILITY	SCORE	CATEGORY
Low	1	0 - 25th percentile
Medium	2	25 - 75th percentile
High	3	75 - 95th percentile
Very high	4	>95th percentile

From the rating of each of these sub-criteria, two climate vulnerability scores are calculated:

- A "vulnerability to extreme weather events" score is obtained by calculating the average between the scores obtained for the sub-criteria «Extreme precipitation» and «Cyclones».
- A "vulnerability to chronic deteriorating climate conditions" score is obtained by calculating the average between the scores obtained for the sub-criteria «Water stress», «Heat stress» and «Sea level rise».

These two climate vulnerability scores are then compared to macro-financial vulnerability as represented in the graphs in Section 2. A country is considered vulnerable to climate shocks if at least one of its climate vulnerability score is strictly greater than 2.

Appendix 2 - Review of financial Instruments

This appendix aims to summarize the various types of innovative financial instruments that the economic literature has identified as appropriate to meet the challenges of low-carbon transition financing. We rely in particular on recent studies to build a (non-exhaustive) list of financial instruments adapted to the situation of double vulnerability as it is defined in our study (Bolton P. *et al.,* 2022; IMF, 2022).

We consider the following groups of financial instruments:

- Debt instruments: *Green bond* and *Sustainability-linked bond;*
- Debt restructuring, cancellation or buyback mechanisms
- Risk retention support mechanisms:
  - Adjustments of existing legal arrangements for debt contracts (such as Climate Resilient Debt Clause);
  - Pre-arranged financing (such as Contingent loan);
- Risk transfer instruments:
  - Insurance instruments;
  - Catastrophe bonds;
- Voluntary or mandatory carbon markets

The table below reviews these instruments, presents their advantages and limitations and identifies favorable (but not required) conditions for their use.

This non-exhaustive review focuses on public financing strategies and does not include instruments dedicated to the private sector, whose objective is not to mitigate the situation of double vulnerability that we consider in our study. Similarly, certain risk transfer instruments such as climate derivatives, only used by financial market stakeholders, will not be included in this review.

Table 4: Non-exhaustive review of innovative financial instruments

INSTRUMENT	FEATURES	VALUE ADDED
Green Bond	Bond with underlying climate assets	• Simple and relatively easy to structure. • International standards and certification schemes already exist. • Introduces mandatory requirements and best practices to monitor the climate impact of an asset portfolio.
Sustainability-linked Bond[14]	Bond financing based on the issuer's "sustainable" or "climate" performance indicators.	• Can target various climate sub-topics (sectoral policies, monitoring system, issuer's practices and performance, etc.) and be tailor-made.
Unconditional debt cancellation/restructuring	One or more creditors temporarily or permanently waive(s) debt service repayments which have been contractually defined with the debtor	• Immediately frees up fiscal space for other public expenses. • When several creditors are involved, helps restore macroeconomic and financial stability in the medium and long term. • In the case of a negotiation with several creditors, avoids debt buybacks.
Debt-for-climate swap	Two types of transaction exist: (i) debt conversion, whereby one or more creditors (often public) waive(s) contractually defined repayments in return for investments in adaptation or mitigation or (ii) debt buyback (generally sovereign bonds) by the issuer, at a discounted price. The difference in expected cash flows before and after buyback is then allocated (partially or fully) to adaptation or mitigation investments.	• Can take place before a default because creditors may have a greater incentive to structure such a transaction compared to a simple unconditional restructuring. • The commitment to finance climate expenses with the saved resources reduces the incentive to use them to repay other creditors. • Does not necessarily signal a default when it is done on a voluntary basis: the negative reputational effect is much lower. • Can be combined with other instruments (with SLB in particular).
Climate Disaster Debt Moratorium (Climate Resilient Debt Clause)	The creditor temporarily waives the payment of interest (and sometimes principal) on a loan in the event of an extreme climate event. A moratorium defines the period and the financial conditions under which the repayment will be rescheduled.	• Provides additional fiscal space (ex-ante negotiated) when needed. • Does not constitute a default so it does not send a negative signal to creditors. • If it applies to a significant part of public debt, it can free up significant fiscal space at the time of the shock.
Public insurance systems (with international solidarity mechanism)	Public international insurance fund coupled with an international solidarity mechanism	• Such an instrument does not currently exist at the global level. Nevertheless, there are mechanisms of this kind at the regional level. • Allows to build diversified asset portfolios and pool the risks at different levels.
Pre-arranged financing (including contingent loan)	Loan whose disbursement(s) is/are triggered by the occurrence of a climate shock	• Provides additional public resources when the shock occurs (pre-negotiated).
Catastrophe Bond	Risk transfer mechanism allowing an insurance company to raise debt disbursed only in the occurrence of a predefined event.	• In the event of a shock, the principal is paid by the investors to the issuer and the repayment may be deferred. • This instrument is attractive for investors because the yield is high for usually short maturities (3 to 5 years).

14 The SLB market is growing rapidly with the volume of funding raised through these instruments reaching USD 100bn in 2021 (International Finance Corporation).

LIMITATIONS	FAVORABLE CONDITIONS OF USE
• Requires critical portfolio size. • Better suited to finance mitigation than adaptation.	• Macro-financial strength (additional indebtedness capacity) • More appropriate to support ambitious mitigation strategies
• Lack of common international standards. • When they exist, financial incentives to meet the targets can be difficult to calibrate and are often insufficient.	• Macro-financial strength (additional indebtedness capacity) • Appropriate to support comprehensive or sectoral adaptation strategies (can also cover mitigation strategies even if Green Bonds are often preferred in this case because less expensive to implement)
• Often occurs just before or once the debtor is in default (creditors' incentive to initiate a restructuring process is low otherwise). • Very lengthy negotiations. • Freed-up fiscal space isn't necessarily allocated to climate investments. • Default is a bad signal: it hinders access to international financial resources for a long time.	• High macro-financial vulnerability (unsustainable public debt dynamic) • Urgent and significant investments needs in adaptation
• Negotiation on climate-related performance indicators can be long and costly. • The limited scale of debt-for-climate swaps is insufficient in most cases to restore long-term public debt sustainability. • The climate commitment is not always senior compared to the commitment to repay residual debt • Risk of indirectly subsidizing other creditors	• Moderate macro-financial vulnerability • Possible only when the creditors base allows for such negotiations between creditors
• The automatic restructuring conditions (loan maturity extension, unaffected NPV, etc.) are currently not uniform and can lead to significant additional costs for the borrower. • The instrument is only effective if it is set up in a standardized way by the country's main creditors.	• Moderate macro-financial vulnerability • When risk retention capacity is moderate (i.e. when the government cannot bear alone the cost of climate disasters and needs support in this respect) • Countries vulnerable to extreme weather events
• The cost of risk premiums remains a major issue for countries with high macro-financial vulnerabilities and must be partially covered by international solidarity. Otherwise, participation is insufficient to ensure an effective risk pooling. • The challenge also lies in precisely defining the subsidiarity of such mechanisms, whose role is to cover only the so-called «non-insurable» risks.	• Low or no risk retention capacity at the national level. • Vulnerability to extreme weather events.
• The negotiation of this type of loan can be relatively long and its pricing may appear unattractive. • May lead to a rapid increase in public debt ratio in case of a climate shock.	• Moderate macro-financial vulnerability • Risk retention capacity is moderate • Countries vulnerable to extreme weather events
• Available for insurers or reinsurers who have already built up significant portfolios. • Requires an active reinsurance market and strong solvency of all players in the financial chain.	• Limited macro-financial vulnerability and existence of a dynamic insurance market. • Risks insurable by the private sector.

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List of acronyms

AFD: *Agence française de développement* (French Development Agency)

COP: Conference of the Parties

DAC: OECD Development Assistance Committee

DSSI: Debt Service Suspension Initiative

ECB: European Central Bank

GDP: Gross domestic product

GFSR: Global Financial Stability Report

IMF: International Monetary Fund

IPCC: Intergovernmental Panel on Climate Change

LDC: Least Developed Countries

LIC: Low-income countries

MIC: Middle Income Countries

OECD: Organization for Economic Co-operation and Development

SDR: Special Drawing Rights

SIDS: Small Island Developing States

SLB: Sustainability-linked bonds

UNFCC: United Nations Framework Convention on Climate Change

USD: US dollar

V20: Vulnerable Group of Twenty

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